

What is Claimed is:

1. 1. A miniature rheometer for analyzing a small quantity sample, comprising:
 2. a first plate and a second plate, forming a pair of plates having a known geometry for confining the sample between the plates, said sample having a volume of 200 microliters or less;
 5. an adjusting device for adjusting the separation of the plates;
 6. an actuating element mechanically coupled to the first plate, which produces a shear strain within the sample by generating a defined small-scale relative motion of the first and second plates;
 9. a sensing element which outputs a position signal indicative for a displacement of at least one of the first and second plates ; and
 11. a feedback circuit for providing force rebalance of the force applied to the sample by the small-scale relative motion of the first and second plates on the basis of the position signal,
 14. wherein an amount of force rebalance is a measure for the shear stress within the sample.
2. The miniature rheometer of claim 1 further comprising:
a sensor-actuating element mechanically coupled to the second plate, which is driven by the feedback circuit to maintain the second plate at a predefined position.
3. The miniature rheometer of claim 2, wherein the sensing element comprises a deformation-sensing element mechanically coupled to the sensor-actuating element, the deformation-sensing element detecting a deformation of at least a portion of the sensor-actuating element to provide the position signal.

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4. The miniature rheometer of claim 1, wherein the feedback circuit drives the actuating element so as to maintain a predefined relative displacement between the first plate and the second plate.
5. The miniature rheometer of claim 4, wherein the second plate is maintained at a fixed position.
6. The miniature rheometer of claim 5, wherein the sensing element comprises a deformation-sensing element coupled to the actuating element, which detects a deformation of at least a portion of the actuating element to provide the position signal.
7. The miniature rheometer of claim 1, wherein the actuating element comprises a driving stage mechanically coupled to the first plate, the driving stage being adapted to generate a small, translational, measurable displacement at a measurable rate.
8. The miniature rheometer of claim 1, wherein the actuating element comprises a piezo-electric actuator so as to produce the small-scale relative motion.
9. The miniature rheometer of claim 8, wherein the piezo-electric actuator comprises a longitudinal metal foil on one surface of which at least one piezo-electric material layer is attached such that a voltage applied to the piezo-electric material layer leads to a deformation in a longitudinal direction with respect to the metal foil.
10. The miniature rheometer of claim 9, wherein the piezo-electric actuator further includes at least one second piezo-electric material layer attached to a second surface opposite of said one surface of the metal foil, said at least one piezo-electric material layer and said second piezo-electric layer being electrically coupled such that the voltage applied to the coupled piezo-electric material layer and the second piezo-electric material layer leads to a deformation of the second piezo-electric material layer which is inverse to that of the piezo-electric material layer.

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11. The miniature rheometer of claim 8, wherein end portions of the piezo-electric actuator are clamped in place by a mechanical assembly.
12. The miniature rheometer of claim 8, wherein the actuator is attached to the first plate by a rigid, thermally-insulating support.
13. The miniature rheometer of claim 12, wherein the first plate is removeably attached to said support.
14. The miniature rheometer of claim 1, wherein said first and second plates are disposable plates.
15. The miniature rheometer of claim 1, wherein the the second plate is supported by a rigid thermally-insulating support.
16. The miniature rheometer of claim 15, wherein said second plate is removably attached to said support.
17. The miniature rheometer of claim 2, wherein the sensor-actuating element comprises a piezo-electric material layer attached to a mechanically-clamped metal foil, said sensor actuating element being adapted to produce a deformation of the metal foil upon application of a voltage.
18. The miniature rheometer of claim 1, further comprising a memory storing a result of a force measurement.
19. The miniature rheometer of claim 1, further comprising a tool for removing excess sample material extending beyond the edges of the pair of plates.
20. The miniature rheometer of claim 1, further comprising a signal processor processing a signal output by the feedback circuit.

21. The miniature rheometer of claim 1, further comprising a normal force measuring means which is adapted to determine a force exerted along a line joining centers of the plates when the plates are positioned above one another.
22. The miniature rheometer of claim 21, wherein the normal force measuring means comprises a piezo-electric actuator element.
23. The miniature rheometer of claim 21, wherein the normal force measuring means is integrated in the sensing element so as to form a combined shear and normal force sensor.
24. The miniature rheometer of claim 1, wherein the actuating element is adapted to generate a rotational displacement between the first and second plates.
25. The miniature rheometer of claim 24, wherein the actuating element comprises a piezo-electric actuator.
26. The miniature rheometer of claim 25, wherein the piezo-electric actuator comprises an elongated metal foil with at least two piezo-electric plates mounted on a single surface of the metal foil such that a defined curvature of the metal foil is obtained when a predetermined voltage is applied to said at least two piezo-electric plates.
27. The miniature rheometer of claim 26, wherein at least two further piezo-electric plates are mounted on the other surface of the metal foil so as to generate the defined curvature when the predetermined voltage is applied to the at least two piezo-electric plates and the at least two further piezo-electric plates.
28. The miniature rheometer of claim 27, further comprising an elongated rigid, thermally-insulating support, wherein the metal foil is attached to the support, with a short axis of the metal foil parallel to a longitudinal axis of the elongated support, such that applying the voltage causes a rotational displacement of the metal foil around the short axis.

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29. The miniature rheometer of claim 28, wherein the metal foil is attached to the elongated support by means of a narrow slot.
30. The miniature rheometer of claim 24, wherein the sensing element comprises a torque sensor.
31. The miniature rheometer of claim 30, wherein the torque sensor is coupled to the second plate by a rigid, thermally-insulating support.
32. The miniature rheometer of claim 31, wherein the torque sensor comprises a rigid shaft having at least two piezo-electric plates attached to a surface of the shaft such that one end of each plate is tangential to the surface and the other end of each plate is tethered to a second rigid support.
33. The miniature rheometer of claim 32, wherein the torque sensor further comprises a rotation-sensing element generating a signal upon rotation of the shaft.
34. The miniature rheometer of claim 33, wherein said rotation-sensing element is a piezo-electric plate, one end of the piezo-electric plate being tangential to the surface of the shaft, the other end being tethered to the second support.
35. The miniature rheometer of claim 30, wherein the torque sensor comprises two or more metal foils having at least one piezo-electric plate attached thereto, one end of each metal foil mounted on a rigid shaft to thereby radially extend therefrom, the other end being attached to a rigid support, wherein a voltage applied to the piezo-electric plates produces a torque parallel to the rigid shaft.
36. The miniature rheometer of claim 35, wherein the torque sensor comprises a rotation-sensing element for detecting a rotational motion around the shaft and outputting a signal in accordance with the rotational motion.
37. The miniature rheometer of claim 36, wherein the rotation-sensing element is a piezo-electric element

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38. The miniature rheometer of claim 34, wherein the voltage supplied to the piezo-electric plates is an indication of the shear in the sample.
39. The miniature rheometer of claim 1, wherein the sensing element comprises an encoder means which detects the relative displacement of the first and second plates.
40. The miniature rheometer of claim 1, further comprising means for applying varying environmental conditions to the sample, wherein the environmental conditions include at least one of temperature, pressure at a fixed gas composition, composition of a gas atmosphere, electric field, magnetic field, and time of application of one or more of the preceding quantities when adjusted to a predetermined value.
41. An assembly of two or more miniature rheometers as defined in claim 1, further comprising a control unit for controlling operation of the two or more miniature rheometers.
- 1 42. A parallel rheometer for simultaneously analyzing material characteristics of two
2 or more samples, comprising:

3 first and second plates respectively having regions for receiving and confining
4 said two or more samples, the first and second plates being moveable relatively to
5 each other;

6 an actuator adapted to move the first and second plates relative to each other for
7 producing a shear strain within each sample;

8 and at least one sensor associated with each region for simultaneously detecting
9 shear stress within each sample.
43. The parallel rheometer of claim 42, further comprising an environmental condition controller applying varying environmental conditions to the two or more samples.
44. The parallel rheometer of claim 43, wherein the environmental condition controller is adapted to vary at least one of temperature, pressure at a fixed gas composition, composition of a gas atmosphere, electric field, magnetic field, and time of

application of one of the preceding quantities when adjusted to a predetermined value.

45. The parallel rheometer of claim 43, wherein the environmental condition controller is adapted to individually vary the environmental conditions of at least one of the samples.
46. The parallel rheometer of claim 42, wherein the first and second plates comprise a shear plate and a fixed plate which are arranged in a parallel manner to each other and which are separated from each other by an adjustable distance.
47. The parallel rheometer of claim 46, wherein at least the shear plate comprises a raised region of predetermined dimension so as to confine a sample between the shear plate and the fixed plate.
48. The parallel rheometer of claim 46, comprising a translation stage coupled to the shear plate for moving the shear plate linearly and in a parallel manner with respect to the fixed plate in accordance with a required type of motion.
49. The parallel rheometer of claim 46, wherein the shear plate comprises two or more micromachined electrostatic drives, each micromachined electric drive corresponding to a sample.
50. The parallel rheometer of claim 42, wherein the shear stress sensor comprises a micromachined silicon plate which is tethered to a surrounding substrate by at least two tethers, each having a piezo-resistive element responsive to a deformation of the tether.
51. The parallel rheometer of claim 50, further comprising signal-generating circuitry for generating a signal proportional to the deformation of the tethers.
52. The parallel rheometer of claim 42 wherein the shear stress sensor comprises a stress-sensing material of a defined stress-optic coefficient indicating one of bire-

fringence and retardation of linearly polarized light passing the stress-sensing material, as a function of applied stress/unit path length.

53. The parallel rheometer of claim 52, wherein polarized light is input into said stress-sensing material, and light having passed the stress-sensing material is guided through a polarizer means having a polarization direction different from and preferably perpendicular to that of the input light.
54. The parallel rheometer of claim 52, wherein the input light is polarized by a single mode input fiber.
55. The parallel rheometer of claim 54, wherein said stress-sensing material is a short portion of the single mode input fiber.
56. The parallel rheometer of claim 52, wherein a single mode fiber comprises a light input portion, a middle portion as the stress-sensing material, and a light output portion.
57. The rheometer of claim 52, wherein a surface of the stress-sensing material, which may be brought into contact with a sample is provided with a reflective layer, and the polarized light is directed to the stress-sensing material by an oblique angle with respect to the reflective layer, whereby the polarizer means is positioned to receive light reflected by the reflective layer.
58. The parallel rheometer of claim 52, further comprising a detector arranged so as to detect a signal output by the stress-sensing material.
59. The parallel rheometer of claim 42, wherein the actuator comprises an actuator element for each sample which is symmetrical with respect to an axis normal to a surface of the sample, wherein the actuator element is rotatable around said normal axis by a driving means.

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60. The parallel rheometer of claim 59, wherein the driving means comprises a motor and an encoder for generating a rotational displacement of each of the actuator elements.

61. The parallel rheometer of claim 42, wherein the at least one sensor comprises a normal force sensor detecting a force component which is perpendicular to a shear force.

62. The parallel rheometer of claim 61, wherein the normal force sensor is provided in each region.

63. The parallel rheometer of claim 61, wherein the normal force sensor is integrated in a shear force sensor provided at each region.

1 64. A rheometer, comprising:

2 a pair of plates spaced apart from each other by a defined distance for receiving
3 and confining a sample therebetween,

4 an adjusting means which adjusts the distance between the plates,

5 a driving means coupled to at least one of the plates, which generates a relative
6 motion between the plates without changing the distance, and

7 a shear stress sensor, the shear stress sensor comprising a stress-sensing mate-
8 rial of a defined stress-optic coefficient indicating one of birefringence and retar-
9 dation of linearly polarized light passing the stress-sensing material, as a function
10 of applied stress/unit path length.

65. The rheometer of claim 64, wherein polarized light is input into said stress-sensing material, and light having passed the stress-sensing material is guided through a polarizer means having a polarization direction different from and preferably perpendicular to that of the input light.

66. The rheometer of claim 65, wherein the input light is polarized by a single mode input fiber.

67. The rheometer of claim 66, wherein said stress-sensing material is a short portion of the single mode input fiber.
68. The rheometer of claim 64, wherein a single mode fiber comprises a light input portion, a middle portion as the stress-sensing material, and a light output portion.
69. The rheometer of claim 64, wherein a surface of the stress-sensing material, which may be brought into contact with a sample is provided with a reflective layer, and the polarized light is directed to the stress-sensing material by an oblique angle with respect to the reflective layer, whereby the polarizer means is positioned to receive light reflected by the reflective layer.
70. The rheometer of claim 64, further comprising a detector arranged so as to detect a signal output by the stress-sensing material.

1 71. A sensor element for outputting a signal in response to a mechanical deformation
2 applied to the sensor element, comprising:
3 a sample plate arranged within an opening of a substrate;
4 at least two tethers, one end of each tether being attached to the sample plate,
5 the other end of each tether being attached to the substrate so as to support the
6 sample plate;
7 a piezo-resistive portion in each of the tethers; and
8 first and second electrically conductive lines formed on the tethers and the sub-
9 strate, connecting each piezo-resistive portion with first and second contact pads
10 formed on the substrate,
11 wherein the piezo-resistive portion of one of said at least two tethers is adapted to
12 generate a maximum change of its internal resistance when a shear force is ap-
13 plied to the sample plate, and wherein the piezo-resistive portion of the other one
14 of said at least two tethers is adapted to generate a maximum change of its inter-
15 nal resistance when a force normal to the sample plate is applied.

72. The sensor element of claim 71, wherein at least four tethers are provided, respective two of said tethers forming a shear sensor portion having a first shear tether and a second shear tether, and a normal force sensor portion having a first normal tether and a second normal tether, respectively.
73. The sensor element of claim 72, wherein each piezo-resistive portion comprises a doped semiconductor material.
74. The sensor element of claim 73, wherein the first shear tether comprises the doped semiconductor material at least partially at a region of tension, and the said second shear tether comprises the doped semiconductor material at least partially at a region of contraction, when a shear force is applied in a predefined direction, wherein the doped semiconductor material is a piezo-resistive material.
75. The sensor element of claim 73, wherein the first normal tether comprises the doped semiconductor material at least partially at a region of tension, and the second normal tether comprises the doped semiconductor material at least partially at a region of contraction, when a normal force is applied in a predefined normal direction, wherein the doped semiconductor material is a piezo-resistive material.
76. The sensor element of claim 71, wherein a length dimension of the sample plate is smaller than 5 mm.
77. A sensor element array comprising a plurality of sensor elements as defined in claim 71, formed on a common substrate.